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Assessing the effectiveness of the EU Emissions Trading Scheme[1]

Tim Laing[2], Misato Sato[3], Michael Grubb[4] and Claudia Comberti[5]

Abstract

As an increasing number of countries, regions, cities and states implement emissions trading policies to limit CO_2 emission, many turn to the experience of the European Union's Emissions Trading Scheme, the largest greenhouse gas emissions trading system in operation. The aim of this paper is to survey the body of literature developed over the past eight years of the scheme's existence, particularly those focusing on three key challenging areas of evaluation: (1) emissions abatement in relation to the balance with economic objectives; (2) investment and innovation impacts; and (3) profits and price impacts. Among the key conclusions is that the lack of flexibility in the structure of the EU ETS cap, and its inability to adjust to radically altered wider economic conditions in the shape of the financial crisis, threatens to undermine its efficacy in providing incentives for abatement.

JEL: Q54, Q58, H23

Key words: EU ETS; emissions trading; cap and trade;
industrial emissions; climate change mitigation policy

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1. Introduction

The EU Emissions Trading System (EU ETS) is Europe's flagship tool to meet its carbon mitigation objectives. It remains the largest example of emissions trading in operation today, encompassing over 11,500 installations across 30 countries[6] and covering approximately 40% of total EU emissions. Its *environmental* impact can be assessed against two specific primary objectives:

i. To reduce GHG emissions efficiently, at a negotiated balance of cost and environmental gain;
ii. To promote corporate investment in low carbon technologies (both energy efficiency and low carbon energy sources).

In its fundamental design, the EU ETS achieves a main environmental objective of capping power and industrial greenhouse gas emissions. However, understanding its wider impact is crucial.

Its journey on a 'rocky road' thus far, has been subject to close scrutiny closely by the media, and academic and grey literature. Whilst accredited as an innovative and adaptive policy instrument, which has experienced a steep learning curve during the first two phases of its existence, several major setbacks have been well documented. These include over-allocation of allowances that led to the inevitable price crash, large windfall profits from generous free allocation and issues with financial fraud.

Imperfect as it is, its eight years of experience has offered ample data and has produced a new and enormous wave of *ex-post* ETS evaluation studies within the environmental economics literature. Scores of papers have evaluated and discussed the scheme's performance, examining numerous aspects such as mechanism design, effectiveness and political trade-offs. These works have informed policy makers not only in Europe but much wider, as new generations of carbon pricing policies are emerging or in planning worldwide and they look to Europe for lessons already drawn.

[6] Norway, Liechtenstein and Iceland joined the scheme in Phase II, although Iceland was not required to submit a NAP for the second phase, as Icelandic installations falling within the scope of the EU ETS could be exempted.

It is surprising then, that the growing literature on EU ETS ex-post evaluation has been subject to systematic synthesis only a handful of times. The notable contributions in this vein include Convery (2009), Ellerman et al (2010), Wrake et al (2012) and Martin et al (2012). The former study reports results from a survey conducted by asking peers to identify the most interesting and influential work in the area of EU ETS. Under a number of topic headings – emissions reductions, allocation, competitiveness, distributional issues, and markets & finance – it outlines the research questions covered and summarises each paper's contribution, rather than a synthesis of the results across studies. Ellerman et al (2010) provide a comprehensive overview, whilst Wrake et al (2012) highlight some of the key areas of contention during the first two trading phases where lessons were learnt (allocation, the electricity sector, uncertainty and price volatility, as well as competitiveness) by drawing on the existing empirical literature.

This paper aims to contribute to these on-going efforts and also more generally to the learning process around unilateral carbon pricing policies which are proliferating globally (see Grubb 2012). We focus on three areas of assessment of the EU ETS encompassing objectives, the functioning and the side effects of the mechanism. Namely, we will review the evaluation approaches and the results of papers to evaluate the following questions:

- Has the EU ETS contributed towards emissions reductions?
- Has the EU ETS induced incentives for investment in low-carbon technology?
- What has been the impact of the EU ETS on profits and product prices?

Doing so reveals the enormity of the task of disentangling the effects of the EU ETS from a multitude of factors including the global recession and establishing causal relations between the ETS and outcomes, as more data becomes available for analysis. It also shows how, to face up to the challenge, researchers are using creative and advanced approaches to work around methodological and data obstacles.

This paper is structured to address the questions outlined above. Section 2 focuses on one of the primary objectives of the EU ETS - to reduce GHG emissions efficiently. In addition to the existing literature, we also draw on emerging data on emissions to assess its impact. Section 3 asks whether and how the EU ETS has impacted investment and innovation thus far. Section 4 then synthesises the literature examining the impact on process and profits, presenting the variety of methods used and results obtained. Some concluding comments are presented in Section 5.

2. Emissions and Abatement impacts

One of the crucial objectives of the EU ETS is to deliver a capped level of emissions from the power and industrial sectors within the EU, as reflected in its official objective to 'promote greenhouse gas (GHG) reductions in a cost-effective and economically efficient manner' (European Commission 2003). In this aim it has been successful, but this does not necessarily imply abatement from business as usual.[7] Disentangling the impact of the EU ETS from other factors is complex as it requires assessment against a 'counterfactual' estimate. Indeed, Convery (2009) highlights the lack of discussions around the counterfactuals in studies investigating EU ETS impacts on emissions. This section begins by synthesising the literature which has sought to quantify the abatement that has occurred, mostly for the period before the financial crisis.

2.1 Pre-financial crisis

Studies that try to establish a link between the EU ETS and emission patterns so far predominantly cover the first four years of the ETS (Table 1). This is perhaps because of time lags in publication but also due to the difficulties with establishing credible econometric 'counterfactuals' after a large economic downturn.

The majority of studies follow a similar methodology, econometrically estimating emissions without the EU ETS, and comparing verified emissions against this scenario (Table 1). Using this approach Ellerman and Buchner (2008) estimate abatement from Phase I (2005-2007) in the range of 120-300 $MtCO_2$, with a best estimate of 200 $MtCO_2$. A similar study by Delarue et al (2008) estimate that the carbon price signal brought about emissions reductions in the power sector of 90 $MtCO_2$ in 2005 and 60 $MtCO_2$ in 2006.

[7] The overall cap of the EU ETS has been met, but this does not necessarily imply that all firms have been completely compliant, for example in Germany in 2007 sixteen operators did not surrender allowances in time (EEA 2008).

Anderson and Di Maria (2011) use a dynamic panel data model to estimate the level of abatement in Phase I of the EU ETS by comparing verified emissions with an estimated business-as-usual scenario, estimating total abatement of 247Mt CO_2.

Deutsche Bank projections in 2010 for Phase II and Phase III estimate required residual abatement in 2008 after the use of offset credits at 38Mt (Deutsche Bank 2010). However their estimates for 2009 and for 2010-2012, business as usual emissions are below that of the ETS cap providing an indication that Phase II would show a surplus of credits that can be banked forward to Phase III.

Abrell, Ndoye-Faye and Zachmann (2011) provide a novel alternative to the problem of producing counter-factual scenarios. Combining CTL data with firm-level turnover, employment and profit data from the AMADEUS database, they control for economic activity, finding that emission reductions in 2007-2008 were greater than for the period 2005-2006, *ceteris paribus*, indicating that the EU ETS had a stronger effect in Phase II compared to Phase I. The study was also able to highlight the specific sectors that contributed most to the reductions (non-metallic minerals and basic metals), and the least (electricity and heat).

Another alternative method to producing counterfactual scenarios is the surveying of EU ETS participants to try and analyse their behaviour. This was an approach conducted by Point Carbon (2009), with anecdotal evidence suggesting that 60% of companies reported abatement or planned abatement in both 2008 and 2009.

Table 1: Estimates of emissions abatement from the EU ETS

Study	Methodology	Key Results
Ellerman and Buchner (2008)	Econometric modelling	Abatement from Phase I in the range of 120-300MtCO_2
Delarue et al (2008)	Econometric modelling	Power sector emissions reductions of 90MtCO_2 in 2005 and 60MtCO_2 in 2006
Anderson and Di Maria (2011)	Dynamic Panel data model	Total abatement in Phase I 247MtCO_2
Deutsche Bank (2010)	Econometric modelling	Residual abatement in 2008 of 38MtCO_2; 2009 emissions below BAU

New Carbon Finance (2009)	Econometric modelling	40% of the 3% fall in 2008 emissions due to the EU ETS
Abrell et al (2011)	Econometric modelling	2007-2008 emissions reductions 3.6% larger than 2005-2006 reductions
Egenhofer et al (2011)	Econometric modelling	2008-2009 emission intensity improvements attributable to the EU ETS 3.35% per annum.
Point Carbon (2009)	Anecdotal evidence	60% of firms reported abatement or planned abatement in 2008 or 2009

Between these "top down", and sector-based "bottom up" evaluations, the existing literature points to ***attributable*** emission savings in the range 40 – 80 MtCO2/yr, annual average (and point estimates of particular years) to date. This is about 2-4% of the total capped emissions, which is much bigger than the impact of most other individual energy-environmental policy instruments.

Estimating the type of abatement is also methodologically difficult – evidence has emerged that the main abatement option in the power sector (and also in the EU ETS as a whole) has been to switch to gas-based generation plants in place of coal. The evidence of this is in the close correlation found between movements in the carbon price with movements in the coal-gas spread throughout most of Phase I and II (Ellerman and Buchner 2008).[8]

Evidence from other sectors is sparse, although there is some evidence that abatement has occurred in unexpected areas. Cement contributes about 8% of EU ETS emissions, arising both from burning fuel to provide heat for the kilns and also from the chemical processes that covert limestone into clinker. The cement production sector was not seen as having significant abatement opportunities, yet abatement has occurred through some kilns moving toward low-carbon alternative fuels including waste and biomass, and cement of lower clinker intensity having been developed and therefore reducing the process emissions embodied in the product (Grubb *et al.,* forthcoming, Ellerman et al 2010).

[8] The coal-gas spread is the difference between the price of coal and natural gas. If this increases it increases the cost of the major abatement option, driving up the price of EU ETS allowances.

In sum, there is some early evidence of a small but non-trivial impact on emissions abatement. There is no one silver bullet solution to estimating this impact, and future assessments are likely to continue to rely on methods across the board.

2.2 Post-financial crisis

The financial crisis that hit in 2008 affected not just European production, but also European emissions, and thus the EU ETS. Business-as-usual conditions changed dramatically, affecting the estimations of abatement. Despite these radical changes there is little literature assessing the emissions impacts of the EU ETS post-2008. A chief reason for this is the lack of data available to assess the impacts, due to the complexity and on-going nature of the crisis, and the lag-time to release of sufficient levels of emission data.

Declercq et al. (2010) estimated the impact of the recession on emissions from the European power sector at approximately 150 $MtCO_2e$, through lower electricity demand, lower fuel prices, offset slightly by the lower carbon price. A report commissioned by the UK's Climate Change Committee on the impact of the economic downturn on UK GHG emissions (Cambridge Econometrics 2009) supports these findings, and they seem to indicate that the reductions in overall EU emissions that have occurred since the inception of the EU ETS are more the result of the impacts of the financial crisis than the EU ETS.

Egenhofer et al (2011) extended Ellerman and Buchner's approach to 2008-2009 data, finding stronger abatement in 2008-2009 than in 2006-2007, with emission-intensity improvements attributable to the EU ETS rising to 3.35% per annum compared to 1% in the earlier period. The study extended Ellerman's work by disaggregating the numbers, allowing a calculation for (non-combustion) industrial facilities finding that abatement in this sector was weaker in Phase II than for the scheme as a whole.

A further study shows that 40% of the 3% fall in 2008 emissions compared to 2007 can be attributed to EU ETS abatement, larger than the 30% they attribute to the decline in industrial output (New Carbon Finance 2009).

The Sandbag (2011a) analysis highlights the scale of the surplus of allowances that have been accrued in the EU ETS, from both previous over-allocation and the financial crisis, finding that in 2011, 77% of EU ETS installations held surplus allowances. The estimates suggest that 855MtCO_2e of excess allowances will accrue to industry by the end of Phase II, of which 672MtCO_2e will be banked forward into Phase III – with the greatest surpluses estimated accrued in the industrial sectors, mainly steel (165Mt) and cement (143Mt). The inclusion of aviation may help to increase demand for these surpluses, but as average annual emissions for the sector for 2004-2006 was 219Mt, and free allocation from 2013 onwards is 208Mt, the demand is unlikely to be sufficient to cover the overall surplus (European Commission 2011).

Grubb et al. (2012) present emissions data from both the IEA and CITL to attempt to discern any effect from the EU ETS in broader emission, sectoral and intensity patterns, highlighting the impact of the financial crisis on emission trends, and showing some initial evidence that the crisis has caused a structural break in the evolution of emissions and energy intensity in the EU.

The initial studies on the impact of the EU ETS post-financial crisis have been limited to assessing the immediate years post-crisis. They have reached similar conclusions to studies before the financial crisis – that the EU ETS has led to some small levels of abatement – despite concerns over prices. Whether this abatement has continued throughout the duration of the crisis, especially with the worst of the price collapses in 2011 and 2012, remains to be seen and is an important topic for future research.

3. Impact on Investment and Innovation

3.1 Investment impacts

In addition to capping emissions, another key objective of the EU ETS is to impact decision-making regarding low-carbon technologies. Along with driving short-term switching between fuel types, by setting a price on carbon, the intention is to drive innovation in new low-carbon technologies, incentivise additional investment in low-carbon assets, and reduce investment in carbon-intensive products and processes. However, the speed and scale at which carbon prices can drive this switch in innovation and investment depends on the strength of the price signal created, both in terms of magnitude and long-term credibility. Much of the investment required for the switch to a low-carbon economy is on the timescale of decades; hence a long-term credible incentive is required to shift investment decisions. Assessing such impacts is important because whether the EU ETS has achieved its emissions target via short-term investments, or investments in more long-lived assets, will be an important determinant of the long-term cost of carbon abatement in Europe.

Efforts to quantify the impact of the EU ETS on investment in the economics literature are increasing, yet the challenges are still vast. Firstly, techniques of producing business-as-usual scenarios and comparing performance against reality are difficult on two fronts. Public data on investment in new low-carbon plants, technologies and processes is minimal. In addition the computation of realistic business as usual scenarios – in the context of the largest global financial and economic crisis in the last 80 years and the multiplicity of policy measures that aid Europe's transition to a low-carbon economy – is complex and difficult to verify. In the absence of these methods, assessing the impact of the EU ETS upon investment has been done using assessment against intermediate metrics and through survey and interview data from senior managers at firms under the EU ETS (
Table 2).

A European study involving partners from a number of organisations attempted to assess the impact of the EU ETS on investment by analysing steps in a conceptual investment process (Neuhoff 2011). The process has three main steps for assessing the effectiveness of any policy for incentivising investment. These steps are:

1. The policy must capture the attention of relevant decision-makers
2. The policy must allow companies to assess the new opportunities and challenges relevant to the policy when making operational, investment and strategic decisions
3. The policy must provide an enabling environment that allows businesses to realise investment projects.

The study consisted of a number of constituent analyses focusing on survey techniques to assess the effectiveness of the EU ETS in meeting these steps.

Overall, the study concluded that the EU ETS had achieved some degree of capturing the attention of decision-makers – but climate policy generally is seen as less important than other aspects determining investment. The study stresses that the EU ETS has set a cap on emissions, with a legal structure that leads to a decline up until 2050; however, elements of the scheme such as the inclusion of international credits from the CDM undermine some of the stringency set by the cap, and the clarity of the policy. For providing clarity for decision-makers the carbon price has contributed to bringing the issue into the framework of managers – but uncertainty about the level, and importantly the existence of, the future carbon price may reduce some clarity in relation to investment decisions. It is also important to note that other factors such as access to fuel, public perception, and technology-specific support policies also play crucial roles in the investment decisions of power generators (ISI-Frauhofer 2010).

One of the constituent studies of the Neuhoff study, Martin et al (2011), conducted a survey of almost 800 manufacturing companies across six European countries, exploring the impact of the EU ETS on climate-change related measures and clean innovation. The study looked at both product innovation where firms change product lines to lower-carbon alternatives and process innovation where firms look to reduce the carbon impact of current production processes, finding that a large proportion of firms have pursued some measures to reduce GHG emissions – the majority of which have undertaken energy or GHG saving measures relating to their manufacturing or core processes. This study supports the overall conclusion of its parent study in that there has been some impact from the EU ETS on investment and innovation, at least anecdotally, but this effect is dependent on the stringency of the scheme – potentially highlighting the need to strengthen the overall signal emanating from the EU ETS.

Table 2: Studies estimating impact of EU ETS on investment and innovation activities

Study	Methodology	Results
Martin et al (2011)	Survey of manufacturing companies	• Large proportion of firms pursued some measures to reduce GHG emissions • Strong positive association between firms' expectation regarding stringency of the cap and overall innovation in GHG saving processes or products.

Rogge et al (2010)	Survey of German power sector	• Limited impact on innovation due to its lack of stringency in its early Phases and its relatively lower importance than other context factors • Impact on investment has been small so far, CO_2 has now become a part of the investment appraisal of power sector construction
Hoffman (2007)	Survey of managers in German power sector	• EU ETS has become a main driver for small-scale investment decisions with short amortization times • Little impact on large scale investment decisions in power plants or research and development
Petsonk and Cozijnsen (2007)	Case studies in France, Germany, Netherlands and UK	• Innovative activity in a number of sectors both within the EU ETS driven by the carbon price directly, and in sectors outside, for which the potential to sell offsets into the scheme was driving innovation
Kenber et al (2009)	Survey of firms within and outside the EU ETS	• ‘all other effects are being swamped by the credit crisis’ • EU ETS had moved the climate debate into the boardroom
Aghion et al (2009)	Investigation of responses to EU Community Innovation Survey	• Found that energy efficiency and reducing environmental impact were ranked lowest of innovation motivation
Anderson et al (2011)	Survey of Irish EU ETS firms	• Find that EU ETS had been successful in stimulating moderate technological change
Hervé-Mignucci (2011)	Survey of corporate investment communications for 5 most carbon-constrained EU firms	• During the early years of the EU ETS non-climatic considerations • In Phase II of the scheme there were clearer investment-related responses

Rogge et al (2010) conducted a survey analysis of the German power sector, and found that the EU ETS had had a limited impact on innovation due to its lack of stringency in its early Phases and its relatively lower importance than other context factors. Although the overall impact on innovation has been limited, the study found effect in some areas such as a strong increase in corporate CCS research and has strengthened existing incentives to improve efficiency in, and the retrofitting of, coal plants. They also found that although the impact on investment has been small so far, CO_2 has now become a part of the investment appraisal of power sector construction.

Earlier studies investigating the impact of the EU ETS followed a similar survey method. Hoffman (2007) conducted a survey of managers to investigate the impact of the EU ETS on corporate investment decisions concluding that companies were integrating carbon costs into investment decisions. The study found that the EU ETS has become a main driver for small-scale investment decisions with short amortization times. In contrast by 2007 it had had little impact on large scale investment decisions in power plants or research and development.

Petsonk and Cozijnsen (2007) looked at a small number of case studies in France, Germany, the Netherlands, and the UK, finding innovative activity in a number of sectors both within the EU ETS driven by the carbon price directly, and in sectors outside, for which the potential to sell offsets into the scheme was driving innovation.

Kenber et al (2009) conducted a small survey of firms both within the EU ETS and a small selection outside who face indirect impacts through, for example, electricity prices. None of the companies within the study could quantify the negative bottom line impact from the EU ETS – although the timing of the study may have had an effect on this with one company reporting that 'all other effects are being swamped by the credit crisis'. The study did find that the EU ETS had moved the climate debate into the boardroom and into the decision-making realm of senior management, but had not profoundly altered how management ran businesses.

Aghion et al (2009) investigated the responses to the EU's 2004-2006 Community Innovation Survey, finding that 'improving energy efficiency' and 'reducing environmental impact or improved health and safety' were ranked lowest in importance when looking at innovation motivations. They attribute this result, in part, to the low and volatile carbon price from the EU ETS in Phase I.

Anderson et al (2011) surveyed Irish EU ETS firms – investigating technological change during Phase I. They found that 48% of respondents reported employing new machinery or equipment, 74% made process or behavioural changes and 41% reported switching fuels – contributing to emissions reductions.

Hervé-Mignucci (2011) surveyed corporate investor communications for the five most carbon constrained European utilities in order to investigate the incentive that the EU ETS has created to invest in low-carbon generation. The paper finds that during the early years of the EU ETS non-climatic considerations, including strategic decisions focusing on the move towards regional utility businesses, and wider regulations, such as those relating to NOx and SO_2 and those relating to energy market liberalisation, were most prominent. In comparison at the beginning of Phase II of the scheme there were clearer investment-related responses to the presence of the scheme, including cancellation of highly carbon-emitting plant. Whether this trend has continued in the wake of the financial crisis is difficult to assess from this work as the time period covered is from 2004-2009.

These studies mirror the overall findings of the Neuhoff et al (2011) study in that there is some evidence of the EU ETS being factored in to decision-making, but not on the scale that is required to impact either the types of long-term capital projects needed to meet the long-term targets that the EU has set out, or to incentivise the type of innovation required to bring down the cost of meeting these targets.

Assessing the investment effect of the EU ETS has proved to be extremely difficult; evidence has had to be gleaned from its impact on managerial decision-making. The inability to produce counter-factual scenarios in light of the financial crisis makes quantitative estimation of investment difficult. In the longer term, as more data on the construction of new generating fleets becomes available, assessing the impact of the EU ETS on the scale and type of investment decisions may become clearer.

An early example of such analysis is found in Calel and Dechezleprêtre (2012) who combine difference-in-differences and matching methods that pairs EU ETS firms with similar non-EU ETS firms, comparing the change in patenting activity between the two groups– with results showing that the EU ETS between 2005 and 2009 has encouraged innovation in clean technologies among regulated companies. This approach, although preliminary, offers a number of promising areas for future research.

The emergence of new data is also helping to evaluate the effect of the EU ETS on investment. Lofgren et al (2013) use Swedish firm level data to conduct an econometric ex-post evaluation of the impact of EU ETS on both small and large investment decisions, finding no significant effect. A major question mark hangs over the EU ETS regarding its ability to incentivise the types of investment in long-term low-carbon assets. The lower than anticipated price levels, along with its volatility, a result as much of regulatory uncertainty as economic fluctuations, have helped to open up this question. In a similar fashion to assessing abatement, assessing the investment that the EU ETS has driven is a difficult exercise. The main focus of research has not been on the production of counterfactual scenarios, but more on surveying key actors, such as managers of major utilities and industries. The evidence from this work highlights that although the EU ETS has been instrumental into moving the discussion of carbon into the boardroom – and thus becoming a factor in decision-making – the scale of the issue has not been sufficient to play a crucial role in driving the investment in the types of long-lived low-carbon assets that are required. There is evidence that there have been impacts in terms of incentivising some types of small-scale investment decisions – but not on the scale required. In a similar fashion to abatement activity, the lack of clear price signals from the EU ETS – a result of the surpluses available to regulated facilities – has undermined the overall objective and again has motivated the call to strengthen the EU ETS.

4. Impact on product prices and profits

When a firm faces an increase in input costs, they can choose between three options: (1) absorb the cost by reducing profit margins; (2) decrease costs by improving the efficiency of their operations; or (3) pass the additional costs onto the consumer. The extent to which firms pass through such CO_2 opportunity costs under the EU ETS is a question at the core of the analysis on carbon leakage[9] and windfall profits – the latter of which represents an unintended[10] but highly controversial outcome of the EU ETS,

[9] Carbon leakage refers to the shifting of productive capacity from one country to another as a result of differential emissions pricing policy It is nowadays common to distinguish 'investment leakage' where new investments in energy intensive production facilities take place outside of a carbon pricing zone such as the EU ETS, and 'product leakage' where the share of EU producers in both export and internal markets diminishes. This distinction, however, remains fuzzy because in the end 'investment leakage' must translate itself into 'product leakage' and vice versa. Two channels of carbon leakage have also been discussed: (decreasing) market shares and profit margins.

[10] The generation of windfall profits as a consequence of free allocation has been known and highlighted in the emissions trading literature since very early stages e.g. Burtraw et al (2002)

with implications for the distribution of economic surpluses among producers and consumers, and also between sectors regulated by the scheme.

Price adjustment behaviour of firms under the EU ETS has been examined using both modelling and econometric techniques, both of which are grounded in sound economic theory. This strand of analysis refers back to the literature on exchange rate pass-through (exchange rate pass-through by German exporters have been examined by Knetter, 1993; Goldberg and Knetter, 1997; Stahn, 2006; and Gaulier et al., 2008 for example), based broadly on the simple mark-up model of imperfect international competition (Dixit and Stiglitz, 1977, Dornbusch, 1987).

4.1 Studies using modelling approaches

Both static and dynamic bottom-up (engineering economic) models have been used to analyse the likely impacts of the EU ETS to product prices and windfall profits, mostly for the power sector but also for some industry sectors. The Nordic markets are examined by Kara et al. (2008) and Oranen (2006), and the UK and Spanish power sectors by IPA (2005) and Linares et al. (2006) respectively. Multiple countries are modeled by Sijm et al. (2005), Chen et al. (2008) and Lise et al (2010). These simulations allow the examining of the influence of market power on pricing behaviour, as well as assumptions about demand elasticity and generation technology portfolios. There is general consensus in these studies that windfall profits are accrued by power companies as a significant part of the costs of CO_2 emission allowances are passed through to product prices, resulting in higher electricity prices for consumers. This holds even in cases of full auctioning. Studies using modeling approaches also show that the ETS-induced increases in power prices depend not only on CO_2 price levels but also on the incidence of market power, and the price responsiveness of power demand. Zhao et al. (2010) investigate the role of different allocation mechanisms on product pricing as well as investment and operations.

4.2 Empirical studies (using econometric and survey approaches)

Motivated by the sharp rise in power prices that coincided with the introduction of the EU ETS in 2005, a wealth of empirical analysis on the power sector provided strong evidence to support the theory that opportunity costs are passed on to consumers (Bunn and Fezzi 2007; Chernyavs'ka and Gulli 2008; Honkatukia et al. 2006; Levy

2005, Frontier Economics 2006). Sijm et al (2005 and 2006) conducted econometric analysis on the impact of carbon price on wholesale electricity prices in the UK and Netherlands and found between 60 and 100% cost pass-through rates. In other words, in line with economic theory, utilities in liberalised markets were found to be passing on the opportunity cost of carbon onto the product prices. Because the firms received the allowances for free in Phase I of the EU ETS, this resulted in large windfall profits (estimated around £800 million /year for the UK power sector in Phase I; IPA Energy Consulting 2005). Zachmann and von Hirschhausen (2008) use an autoregressive distributed lagged model and provide evidence for asymmetric cost pass through in German whole electricity prices - rising EUA prices affect more strongly than falling EUA prices. Chernyavs'ka and Gulli (2008) find that marginal carbon costs are reflected in Italy's electricity price. They also find that cost pass-through rates are influenced by structural factors including the degree of market concentration, the available capacity (whether there is excess capacity or not), the power plant mix in the market and the power demand level (peak vs. off-peak hours).

Further empirical evidence on power sector cost pass through in Phase II (e.g. Cummins et al. 2010) supports the economic theory which says that if firms are passing through the opportunity costs of free allowances anyway, then auctioning has no impact on electricity prices; it merely secures the revenue for the public rather than for firm profits.

For the industrial sectors, further empirical studies have emerged in recent years and the role of industrial characteristics of different sectors in explaining the extent of the cost pass-through are becoming increasingly well understood. Fitzgerald et al. (2009) conducted an assessment of pricing power in six broadly defined industrial sectors in six EU countries, in the context of EU environmental tax reform. They specified a long-run linear price-setting model controlling for domestic production costs (labour costs used as a proxy) and tested whether price setting responds to local (German) and foreign prices (US prices used to proxy world prices). They found that the European Non-metallic minerals sector (cement, lime) had the greatest pricing power, whereas the Basic metals sector and Chemicals emerged as price-takers.

CE Delft (2010) examines the influence of CO_2 spot price on price developments in Europe for eight industrial products, by exploiting the difference in market behaviour between the EU and US (no carbon policy) for years 2005 to 2009.They found a positive and highly significant influence of CO_2 price on the product price for all products examined, with cost pass-through rates ranging from 33% (for polystyrene) to over 100% for diesel, gasoline, hot- and cold-rolled metal products. With the exception of gasoil, the pass-through of prices occurred with a delay of several weeks or more for most of the products examined.

Oberndorfer et al (2010) examine pricing power for select products within the UK's refining, glass, chemicals and ceramics sectors. They found robust evidence behind the influence of EUA prices on pricing in diesel (50%) and gasoline (75%) for which weekly output prices are available, but no evidence of asymmetric pass-through of CO_2 costs. Where such weekly data is not available, they used input price shocks rather than EUA prices (e.g. gas price shocks) to investigate cost pass-through abilities. Robust evidence was found for ceramic goods (>100%), low-density polyethylene film (>100%) and ammonium nitrate (50%) but not for container glass, and mixed for hollow glass (20-25%) and ceramic brick (30-40%). The cost-pass through behaviour across products differs in terms of asymmetry (impacts of ascending and descending EUA price) and dynamics (time-lags present in cost pass-through).

Alexeeva-Talebi (2010) used advanced time-series techniques to estimate a range of vector error correction models (VECMs), which yielded estimates of cost pass-through rates in an oligopoly setting the long-run equilibrium in German energy-intensive sectors (mainly paper and chemicals). Estimating long-run cost pass-through with the presence of market power is of particular interest, because it sheds light on the trade-off between short-term windfall profits and long-run loss of global market share. This paper found that most of the German EU ETS sub-sectors studied[11] have a positive and *flexible* mark-up over marginal costs, and severe implications on profit margins are unlikely. They also found that the impact on the pass-through is

[11] These were paper and paper board; household paper; basic inorganic chemical; fertilisers and nitrogen compounds; primary plastics; perfumes; rubber products; hollow glass; glass fiber; cement lime and plaster, with the exception of dyes and pigments and other glassware.

ultimately determined by the interplay of individual effects working in different directions: for example, market power, market share, product substitutability and the degree to which firms capitalize on the opportunity to increase output price in response to their foreign competitor's mark-up. Based on these findings, the author argued against generous free allowance allocation for most sectors in Phase III; however, the paper also notes that these firms could still be induced to move production outside the EU due to adverse impact on market shares.

An interesting study based on interviews and an analysis of sixteen different sectors in Japan (Ishinabe 2011) also finds evidence that cost-pass through abilities vary by sector and over time. Steel makers in Japan traditionally exercise price-setting behaviour particularly in domestic markets (largely due to product differentiation abilities in high-grade steel). The unusually strong yen in recent times is, however, reducing their strong bargaining power. Paper and pulp, as well as the glass sector, also exhibit ability to transfer costs. Interestingly, the steel makers' price mark-up does not always impact final consumer product prices, but rather, the costs are absorbed gradually along the supply chain (wholesalers, retailers and distributors). Input costs are harder to pass-on for producer in other sectors including automobiles, chemicals, solar panels and home electronics.

Asuka et al (2010) provide evidence to support the high cost pass-through ability exhibited by of Japanese steel makers. They put into perspective the magnitude of the impact of an 11% increase in product prices for hot-rolled thin plate production (the estimated product price increase assuming a carbon price of 3000yen/ tCO_2 and 100% cost pass through using industrial inter-relationship analysis), relative to the price differences between domestic and import prices. The historic trends show that the 11% change in product price is small, relative to historic fluctuations in price differences (between domestic and imports from Korea, China and Taiwan). Moreover, the Japanese's producers' price-setting power is highlighted by the fact that large price differences after 2002 did not affect high domestic prices.

On windfall profits, a study by Sandbag (2011b) estimates, based on analysis of CITL data, that in the current Phase of the ETS a surplus of 240 million EUAs are held by the top ten benefiting companies. This is equivalent to the annual emissions of Austria

($87MtCO_2$), Denmark (64M tCO_2), Portugal (78M tCO_2) and Latvia (12M tCO_2) combined, with an estimated value of 4.1billion EURs (four times the entire EU environment budget over the same period). These ten 'Carbon Fat Cats' are iron and steel and cement companies, the top five being ArcelorMittal, Lafarge, Tata Steel, ThyssenKrupp and Riva Group. Several other studies also highlight through estimations the billions of windfall profits generated under the EU ETS, both through the value of surplus permits and also via the pass through of costs of allowances that are handed out freely (see Table 3)

In sum, the literature studying carbon price cost-pass through using econometric and interview-based approaches provide empirical support to both the theory and pricing behaviour of firms, as well as the predictions by model-based studies which are founded upon these theories. In particular, robust evidence is provided to support the existence of cost-pass through rates ranging from low (30%) for some sectors and high (over 100% for others, by studies using more advanced econometric approaches that allow representation of market power as well as dynamic effects.

Table 3 Estimates of windfall profits accrued by power and non-power sectors

Study	Sector/ Year	Carbon price assumption	Windfall profit estimate
Sijm and Neuhoff (2006)	DE, UK, FR, BE and NLPower sector in Phase I	€20/tCO_2	€5.3-7 billion per year
Martin et al (2010)	EU all sectors in Phase III	€30/tCO_2	€7 -9 billion per year
Maxwell (2011)	UK Power sector in Phase II		£1 billion per year
Point Carbon, WWF (2008)	German and UK Power sector in Phase II	€21-32/tCO_2	€14-34 bn for Germany €6-15 bn for UK
Lise et al (2010)	EU 20 Power sector	€20/tCO_2	€35 billion
Sandbag (2011b)	Top 10 carbon fat cats in Phase II	€17.03/tCO_2	€4.1 billion
CE Delft (2010)	Refining and Iron and steel sectors in Phase I	?	€14 billion

4.3 Impacts of CO2 price cost pass-through and windfall profits on renewables generation and carbon leakage

In electricity, pass-through of marginal (emissions) costs to electricity prices has benefits for renewables and other zero-carbon power generation. If costs are passed through, then as emissions prices rise, profits for low-emissions generators who do not have to face these costs also rise. In many European countries, renewable energy projects receive long-term contracts with fixed electricity prices (feed-in tariffs) and the costs of renewable energy support schemes decline with rising emissions and electricity prices. This raises the political support and credibility of these schemes, which is essential for further investment in innovation in clean generation technology.

There is a long-term issue relating to the returns that low-emissions power generation will receive in such markets. With cost pass-through in competitive markets, the returns to low-emissions generation depend on the marginal unit of generation (often gas in many European countries) and on the carbon price, neither of which bear any relation to the (capital-intensive) cost structure of this type of generation. This raises questions regarding the best form of contract structure, and accounting for the indirect emissions relating to electricity, in an emissions trading scheme. These issues are discussed in more depth in Laing and Grubb (2010).

The impact of cost pass-through on carbon leakage remains ambiguous. Two channels of carbon leakage have been identified - through diminishing market share and profit margins (Droege et al 2009). Empirical studies have shown middle to high ability to pass on carbon costs to consumers for many industrial sectors, indicating that the latter channel is of less concern.

The impact on long-term market share is difficult to estimate, but there is also general consensus in the literature that even for carbon intensive industries, asymmetric carbon pricing is a minor factor that affects market share and investment decisions (Reinaud 2008a and Reinaud 2008b). Like the well documented case of new Aluminium plants being built in Brazil and China, leakage of productive capacity out of Europe as been occurring for some decades, for reasons other than carbon price differentials: labour prices, energy costs, resource availability, secondary legislation, planning and regulatory issues and so on.

4.4 Key lessons on cost pass-through and windfall profits

Assessment of cost pass-through and windfall profits in the EU ETS has moved quickly and many useful lessons can be drawn for other schemes.

In terms of windfall profits resulting from the EU ETS, the scale of windfall profits (billions of Euros per year) has drawn heavy criticism, damaging public perception and credibility of the scheme. It has created winners (companies with surplus allowances such as the fat cats named above) and losers (electricity consumers, both industrial and residential).[12] Windfall profits in essence represent a transfer of income with a few emissions-intensive producers making profits at the expense of consumers. Furthermore, greater windfall profits tend to be accrued by installations with more carbon intensive production under the current allocation procedures,[13] and not surprisingly, the opportunity to gain windfall profits has attracted heavy lobbying activity by the industry.

To address the issue of windfall profits, Phase II allocation plans have made a move away from free allowance allocation, with all power generation installations in the UK required to buy their permits in auction. The EU ETS as a whole is moving in this direction and will move away from free allocation in the power sector, virtually completely, by Phase III.

In terms of cost pass-through, compelling empirical evidence exists to support the existence of pricing power in the form of CO_2 opportunity cost pass-through, not only in electricity but also in industrial sectors. Cost pass-through is desirable from the perspective of reducing emissions as it drives demand side mitigation via demand substitution (Neuhoff 2011). Where prices are passed through to consumers they have the incentive to use less high-carbon products and move towards low-carbon ones. Conversely, where prices are absorbed by industry, firms still have incentives to reduce their carbon content but consumers do not receive the price signal needed to shift to lower-carbon alternatives.

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[12] Electricity consumers are losers relative to a scenario where windfall profits are collected as auction revenue, and redistributed to the consumers or invested in efforts to meet the emissions reduction cap.

[13] In Germany, for example, where coal is the marginal generation technology that sets the price the majority of the time, the impact of the carbon price on product is higher than in countries such as the UK where gas sets the price (Point Carbon 2008).

The empirical studies support the theory that cost pass-through is higher in monopolistic / oligopolistic markets, and in markets where demand is more inelastic whether due to high product differentiation or other trade barriers (Sijm *et al.,* 2009). However, cost pass-through can be restricted by regulatory measures: the large power utilities in France (holding market power) are subject to tight price controls, for example.[14]

5. Concluding remarks

The EU ETS emerged out of the failure of efforts throughout much of the 1990s to introduce a carbon tax in Europe and scepticism about the effectiveness of voluntary agreements. In addition, two Member States – the UK and Denmark – had introduced very different kinds of pilot emission trading schemes, which highlighted the risk of Europe ending up with lots of different, disjointed schemes. Initial resistance in the UK to having its own (albeit demonstrably inferior) scheme superceded by the EU ETS was quickly overcome.

The EU ETS has become well embedded. The high-profile failure of Sarkozy's French carbon tax in 2010 further reinforced the sense that emissions trading is a more feasible route to carbon pricing, though it is also now more widely understood that carbon taxation may *also* have a role – in other sectors, and or at different stages of production chains.

The sequential design of the EU ETS has been central to its development, and enabled many initial inadequacies to be dealt with in later Phases. In Phase III, the centralisation of cap-setting and the move to auctioning in the power sector are radical improvements based directly on the earlier experience.

Despite this, problems remain. An unreasonable number of sectors have been classified as "at risk of leakage" and thus will receive free allowances, which will

[14] Also in the US Acid Rain Program, the state utility commissions deemed that sulphur dioxide (SO_2) allowances – 97.2% of which were given away free by the US Environmental Protection Agency (EPA) each year – were an asset whose value should accrue to customers.

extend problems of potential windfall profits. The dynamics of the market that have led to a pattern of 'periodic instability' in price are still not fully understood. Most fundamental, the resistance to creating a price floor has left the EU ETS as the "residual" system absorbing the impact of both recession and complementary policies on energy efficiency and renewables - creating unnecessary tensions between them and leading to the present collapse in prices.

The EU ETS continues to spark curiosity of researches and the literature continues to grow, and a number of important lessons for design of emissions trading schemes are emerging from it. This paper has contributed by means of synthesis of the discussions and findings in three main areas: abatement, investment and innovation, and profits and prices.

On emissions, over-allocation (in Phase I) and in particular the recession (in Phase II) have reduced the direct impact of the EU ETS on emissions, but the combination of rigorous monitoring and awareness, together with a positive carbon price, has driven some abatement. Disentangling the impact of the EU ETS from other factors is complex, but academic studies with both "top down", and sector-based "bottom up" evaluations point to ***attributable*** emission savings in the range 40 – 80 $MtCO_2$/yr, annual average (and point estimates of particular years) to date (see Table 1). This is about 2-4% of the total capped emissions, which is much bigger than the impact of most other individual energy-environmental policy instruments.

On investment, there are no quantitative (monetised) studies of investment impacts, but the managerial interviews surveyed in this study suggest that the EU ETS has affected investment decisions, but so far only in limited ways: mainly small-scale efficiency related investments rather than being sufficiently clear to drive large long-term investment decisions. The EU ETS has been effective at getting attention to climate change in company boardrooms, which is a prerequisite for such decisions. It also provides a longer-term context that helps to frame company strategic decisions. In this capacity, the EU ETS has probably been effective in helping to deter major carbon intensive investments. This again is a useful precondition – a wise choice in a carbon constrained world and also helping to free up capital that could be turned to low carbon investment.

On innovation, there is evidence that investment and innovation responses are stronger in companies which face a shortage of allowances than in those with surplus allowances – a finding at odds with classical theory but consistent with theories of behavioural economics, which emphasise loss and risk aversion more than pure optimisation. However, the volatile price – and lack of clarity beyond 2020 - has undermined the potential of the EU ETS to drive the large, long-term investments that decarbonisation ultimately requires. For this, more targeted supports – notably the renewable energy policies – have been more directly impactful. Other instruments (like the UK floor price and contracts-for-difference) may help to try and bridge the gap between carbon pricing and other investment drivers.[15]

On profits, free allocation combined with trading creates the potential for 'windfall' profits. The evidence from Phase I and Phase II is that significant windfall profits only endure for a limited time, as policy can and will respond once the evidence is clear – as with the move to auctioning in the EU power sector. Price, and the value it creates, also of course carries the risk of abuse and sometimes fraud, and thus demands strong governance.

It remains unclear whether the EU ETS will have to wait until Phase 4 to solve the outstanding problems. Efforts from researchers on policy evaluation are making important contributions to providing evidence to support these debates and developments.

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[15] The UK is undertaking a major Energy Market Reform package, the main purpose of which is to create a stronger basis for low carbon investment. This includes a system of long-term 'contracts for difference' in which investors are guaranteed a price consistent with a certain minimum level of electricity price – if the actual (market) price is below this level, the government contracts to make up the difference. In addition, the EMR establishes a floor price for CO2, through taxation, at a level which is increased if the EU CO2 price is too low. It is a complex package designed to increase the security of investment, and thereby lower the cost of raising the large amounts of finance required. For details see the UK Energy White Paper on Energy Market Reform (July 2011).

Bibliography

Abrell J, Ndoye-Faye A, Zachmann G, 2011, "Assessing the impact of the EU ETS using firm level data", Bruegel Working Paper 2011/08, Brussels

Aghion P, Veugelers R, Serre C, 2009, "Cold start for the green innovation machine", Bruegel Policy Contribution 12, Brussels

Alexeeva-Talebi V, 2010, "Cost Pass-Through in Strategic Oligopoly: Sectoral Evidence for the EU ETS", ZEW Working paper

Anderson B, Convery F, Di Maria C, 2011, "Technological Change and the EU ETS: The case of Ireland", IEFE Working Paper No. 43

Anderson B, Di Maria C, 2011, "Abatement and Allocation in the Pilot Phase of the EU ETS", *Environmental and Resource Economics* **48** (1) 83-103

Asuka, J, Kanamoto K I, Chun LX, 2010, "Emissions trading and international competitiveness: Case study for Japanese industries", IGES CC Working Paper 2010-004

Bertram G, Terry P, 2010 *The Carbon Challenge: NZ Emissions Trading Scheme* (Bridget Williams Books, Wellington)

British Petroleum, 2011, "Statistical Review of World Energy 2011", Available at http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf Accessed 13 September 2011.

Bunn D, Fezzi C, 2007 *Interaction of European carbon trading and energy prices* (London Business School, London)

Burtraw D, Palmer K, Bharvirkar R, Paul A, 2002, "The Effect of Asset Values of the Allocation of Carbon Dioxide Emission Allowances" *The Electricity Journal* **15** (5) 51-62

Calel R, Dechezleprêtre A, 2012, "Environmental Policy and Directed Technological Change: Evidence from the European carbon market. Grantham Research Institute on Climate Change and the Environment ", Working Paper 75, London

California Air Resources Board, 2011, *Article 5: California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms*, California Environmental Protection Agency, Available at http://www.arb.ca.gov/cc/capandtrade/finalregorder.pdf

Cambridge Econometrics, 2009, "An Impact Assessment of the Current Economic Downturn on UK CO2 Emissions: A final report for the Committee on Climate Change", The Committee on Climate Change, London

CE Delft, 2010, "Will the energy intensive industry profit from the EU ETS under Phase 3?", CE Delft Report 10.7323.74., Delft

CE Delft, 2008, "Impacts on Competitiveness from the EU ETS An analysis of the Dutch Industry", CE Delft Report, Delft

Chen Y, Sijm J, Hobbs BF, Lise W, 2008, "Implications of CO2 emissions trading for short-run electricity market outcomes in Northwest Europe" *Journal of Regulatory Economics* **34** (3) 251–281

Chernyavs'ka L, Gulli F, 2008, "Marginal CO2 pass-through under imperfect competition in power markets" *Ecological Economics* **68**(1–2) 408–421

CITL, 2011, Community Independent Transaction Log of the European Commission, Available from http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=473. Accessed 13 September 2011.

Convery FJ, 2009, "Reflections—the emerging literature on emissions trading in Europe" *Review of Environmental Economics and Policy* **3**(1) 121–137

Cummins M, O'Shea P, Lyons K, 2010, "A Unified Analysis of Emissions and Energy Market Interactions across the EU", Working Paper, Available at SSRN: http://ssrn.com/abstract=2008972 or http://dx.doi.org/10.2139/ssrn.2008972

Delarue E, Voorspools K, D'haeseleer W, 2008 "Fuel Switching in the Electricity Sector under the EU ETS: Review and Prospective" *Journal of Energy Engineering* **134**(2) 40-46.

Declercq B, Delarue E, D'haeseleer W, 2010, "Impact of the Economic Recession on the European Power Sector's CO_2 Emissions", TME Working Paper, WPEN2010-08

Defra, 2006, "Appraisal of Years 1-4 of the UK Emissions Trading Scheme", UK Department for Environment Food and Rural Affairs, London.

Deutsche Bank, 2010, "Carbon Emissions Hard to Credit: ETS Offsets Use Again in Spotlight", Available at http://www.zyen.info/joomla/londonaccord/images/reports/pdf/hard%20to%20credit.pdf

Dixit AK, Stiglitz JE, 1977, "Monopolistic Competition and Optimum Product Diversity" *American*

Economic Review **67**(3) 297–308

Dornbusch R, 1987, "Exchange Rates and Prices" *American Economic Review* **77**(1) 93–106.

Dube S, Awasthi R, Dhariwal V, 2011, "Can the Learning's from International Examples Make the 'Perform Achieve and Trade (PAT) Scheme' Perform Better for India", Emergent Ventures International, Available at http://www.emergent-ventures.com/docs/A%20Discussion%20Paper%20on%20India-s%20Perform%20%20Achieve%20and%20Trade%20%28PAT%29%20Scheme.pdf

Droege S, 2009, "Tackling Leakage in a World of Unequal Carbon Prices", Climate Strategies Report, London

Ecofys, Fraunhofer Institute for Systems and Innovation Research, Oko-Institute, 2009, "Methodology for the free allocation of emission allowances in the EU ETS post 2012: Report on the project approach and general issues", Report to the European Commission, Brussels

EEA, 2008, "Application of the Emissions Trading Directive by EU Member States – reporting year 2008", EEA Technical Report 13/2008

Egenhofer C, Alessi M, GeorgievA, Fujiwara N, 2011, "The EU Emissions Trading System and Climate Policy towards 2050: Real incentives to reduce emissions and drive innovation?", Report, Centre for European Policy Studies, Brussels

Ellerman, A. D. and Buchner B. K ,(2008). A preliminary analysis of the EU ETS based on the 2005-06 emissions data. *Environmental and Resource Economics* **41**(2): 267-87.

Ellerman A D, Convery F J, Perthuis C, 2010 *Pricing Carbon: The European Union Emissions Trading Scheme* (Cambridge University Press, Cambridge)

European Commission, 2003, *EU Emissions Trading System Directive*, European Commission, Brussels

European Commission, 2011, *Inclusion of aviation in the EU ETS: Commission publishes historical emissions data on which allocations will be based*, European Commission, Brussels March 7, 2011

Fitzgerald J D, Keeney M, Scott S, 2009, "Assessing Vulnerability of Selected Sectors Under Environmental Tax Reform: The Issue of Pricing Power" *Journal of Environmental Planning and Management* **52**(3) 413–433

Frontier Economics, 2006, "CO2 trading and its influence on electricity markets. Final report to DTe" Frontier Economics Ltd, London

Gaulier G, Lahrèche-Révil A, Méjean I 2008, "Exchange-Rate Pass-Through at the Product Level" *Canadian Journal of Economics* **41**(2) 425–449

Goldberg P K, Knetter M M, 1997, "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature* **35**(3) 1243–1272

Grubb M, 2009, "Reinforcing carbon markets under uncertainty" Climate Strategies Report, London

Grubb M, 2012, "Cap and trade finds new energy" *Nature* 291 666–667.

Grubb M, Laing T, Sato M, Comberti C, 2012, "Analyses of the effectiveness of trading in EU ETS", Climate Strategies Working Paper, February 2012

Grubb M, Neuhoff K, Hourcade J (forthcoming). *Planetary Economics: The three domains of sustainable energy development* (Earthscan/Taylor & Francis, London UK)

Guerin E, Spencer T, 2011, "Strengthening the European Union Climate and Energy Package", IDDRI and Climate Strategies Report, London

Hepburn C, Grubb M, Neuhoff K, Matthes F, Tse M, 2006, "Auctioning of EU ETS phase II allowances: how and why?" *Climate Policy* **6** (1) 137-160

Hervé-Mignucci M, 2011, "Operating and financial investments by European utilities over 2004-2009: what role for European mitigation policies?" CDC Climat Research Working Papers 2011-9

Hoffman V, 2007, "EU ETS and Investment Decisions: The Case of the German Electricity Industry" *European Management Journal* **25**(6) 464-474

Honkatukia J, Malkonen V, Perrels A, 2006, "Impacts of the European emission trade system on Finnish wholesale electricity prices" VATT Discussion Paper 405, Government Institute for Economic Research, Helsinki

IEA, 2011, *World Energy Balances 2011*. International Energy Agency/ OECD, Paris. Accessed via http://www.esds.ac.uk/ on 17 September 2011

ICE Futures Europe, 2011, "Market Data, Intercontinental Exchange, Inc." Available from https://www.theice.com/marketdata/reports/ReportCenter.shtml. Accessed 13 September 2011

IEA, 2011, *World Energy Balances.* ESDS International, University of Manchester

IMF, 2011, *World Economic Outlook,* Accessed via http://www.esds.ac.uk/ on 17 September 2011

IPA Energy Consulting, 2005, "Implications of the EU Emissions Trading Scheme for the UK Power Generation Sector" Report to the UK Department of Trade and Industry, London

Ishinabe N, 2011, "Analyses of Japanese Business & Environmental Policies - From Interviews to Top Securities Analysts", IGES Policy Report. Downloaded from http://enviroscope.iges.or.jp/modules/envirolib/view.php?docid=3133

Kara M, Syri S, Helynen S, Kekkonen V, Ruska M, Forsström J, 2008, "The impacts of EU CO2 emissions trading on electricity markets and electricity consumers in Finland". *Energy Economincs* **30**(2) 193–211

Kenber M, Haugen O, Cobb M, 2009, "The Effects of EU Climate Legislation on Business Competiveness", GMF Climate and Energy Paper Series 09, Washington DC

Knetter M M, 1993, "International Comparisons of Pricing-to-Market Behavior" *American Economic Review* **83**(3) 473–486.

Laing T and Grubb M, 2010, "Low Carbon Electricity Investment: The Limitations of Traditional Approaches and a Radical Alternative" EPRG Working Papers 1032

Laing T, Junankar S, Pollitt H and Grubb M, 2009, "Global Carbon Mechanisms Annex II: Emissions and demand projections to 2020" Climate Strategies

Levy C, 2005, "Impact of emission trading on power prices: a case study from the European emission trading scheme" University Paris Dauphine and DEA d'Economie Industrielle, Paris

Linares P, Javier Santos F, Ventosa M, and Lapiedra L, 2006, "Impacts of the European emissions trading scheme and permit assignment methods on the Spanish electricity sector". *Energy J* 27(1):79–98

Lise W, Hobbs BF, and Hers S, 2008, "Market power in the European electricity market—the impacts of dry weather and additional transmission capacity" *Energy Policy* **36**(4):1331–1343

Lise W, Sijm J and Hobbs BF, 2010, "The Impact of the EU ETS on Prices, Profits and Emissions in the Power Sector: Simulation Results with the COMPETES EU20 Model", *Environmental and*

Resource Economics **47**, 23–44.

Lofgren, A, Wrake, M, Hagberg, T and Roth, S, (2013), “The Effect of EU-ETS on Swedish Industry’s Investment in Carbon Mitigating Technologies” University of Gothenburg Working Paper in Economics 565

Martin R, Muûls M and Wagner U J, 2010, "Still time to reclaim the European Union Emissions Trading System for the European tax payer", Policy Brief, Centre for Economic Performance, London School of Economics

Martin, R, Muuls M and Wagner U, 2011, “Climate Change, Investment and Carbon Markets and Prices – Evidence from Manager Interviews”, *Climate Policy Initiative and Climate Strategies*

Martin R, Muûls, M, & Wagner, U, 2012, “An Evidence Review of the EU Emissions Trading System, Focusing on Effectiveness of the System in Driving Industrial Abatement” Technical report, Department of Energy and Climate Change.

Maxwell D, 2011, “Hot Air: The carbon price floor in the UK” London: IPPR

McCabe J, 2011, "£7bn windfall for UK utilities from carbon price floor" *Environmental Finance*, 28 June.

Meng L, Guo J, Chain J and Zhang Z, 2011, “China’s regional CO_2 emissions: Characteristics, inter-regional transfer and emission reduction policies”, *Energy Policy* **39** 6136-6144

NAO 2004, “The UK Emissions Trading Scheme: A New Way to Combat Climate Change” UK National Audit Office, 56pp.

NERA 2004, “Review of the first and second years of the UK emissions trading scheme” NERA Economic Consultants, 23pp.

Neuhoff K, 2008, “Tackling Carbon: How to Price Carbon for Climate Policy” Climate Strategies Report

Neuhoff K, 2011, “Carbon Pricing for Low-Carbon Investment: Executive Summary” Climate Policy Initiative and Climate Strategies

New Carbon Finance 2009, “Emissions from the EU ETS down 3% in 2008”

Oberndorfer U, Alexeeva-Talebi V and A Löschel, 2010, “Understanding the Competitiveness

Implications of Future Phases of EU ETS on the Industrial Sectors", ZEW Discussion Paper 10-044, ZEW, Mannheim.

Oranen A, 2006, "The impact of emissions trading on the price of electricity in Nord Pool—market power and price determination in the Nordic electricity market", Master's thesis, Environmental Economics, Department of Economics and Management, University of Helsinki

Paolella M and Taschini L, 2008, "An econometric analysis of emission allowance prices" *Journal of Banking & Finance*, **32** (10), p2022-2032

Parliament of the Commonwealth of Australia 2011, "Clean Energy Bill 2011"

Petsonk, A. and Cozijnsen, J., 2007, "Harvesting the Low Carbon Cornucopia: How the European Union Emissions Trading System (EU ETS) Is Spurring Innovation and Scoring Results, *Environmental Defense*

Philibert C, 2009, "Assessing the value of price caps and floors" *Climate Policy* ***9(6)***

Point Carbon 2008 "EU ETS Phase II – The potential and scale of windfall profits in the power sector" A report for WWF By Point Carbon Advisory Services.

Point Carbon 2009, "Carbon 2009 - Emission trading coming home"

Ponssard JP and Walker N, 2008, "EU emissions trading and the cement sector: a spatial competition analysis" *Climate Policy*, **8** (2008); p. 467-493

Reinaud J, 2008a, "Competitiveness and Carbon Leakage: Ex-post evaluation of the EU ETS" IEA/OECD Information paper, OECD, Paris

Reinaud J, 2008b, "Issues behind Competitiveness and Carbon Leakage. Focus on Heavy Industry" International Energy Agency, IEA Information Paper, OECD/IEA Paris

Reuters 2010**,** "Chinese city dips toe in carbon cap and trade" Available at: http://www.reuters.com/article/2010/02/09/us-china-environment-trade-idUSTRE6182V620100209

Reuters 2011a, "EU, U.N. carbon prices tumble to new record lows" Available at: http://www.reuters.com/article/2011/12/14/us-carbon-market-prices-idUSTRE7BD0RN20111214

Reuters 2011b, "China to launch energy cap-and-trade trials in green push" Available at: http://www.reuters.com/article/2011/03/05/us-china-npc-energy-idUSTRE7240VX20110305

Rickels W, Gorlich D, and Oberst G, 2010, "Explaining European Emission Allowance Price Dynamics: Evidence from Phase II" Kiel Working Papers, No. 1650

Rogge K, Schneider M and Hoffman VH, 2010, "The innovation impact of the EU emission trading scheme – Findings of company case studies in the German Power Sector" *Ecological Economics*, **70** (3) p513-523

Sandbag 2011a, "Buckle Up! Tighten the cap and avoid the carbon crash The 2011 Environmental Outlook for the EU ETS"

Sandbag 2011b, "Carbon Fat Cats 2011: The companies profiting from the EU Emissions Trading Scheme" Sandbag report, June 2011.

Schopp A, Stelmakh K, Vasa A, Boyd R and Neuhoff K, 2011, "Under what conditions is banking of EU ETS allowances effective?" Climate Policy Initiative Berlin

Sijm J, Bakker S, Chen Y, Harmsen H, and Lise W, 2005, "CO_2 Price dynamics. The implications of EU emissions trading for the price of electricity" ECN-C–05-081, Petten, The Netherlands

Sijm J, Neuhoff K, and Chen Y, 2006, "CO2 cost pass through and windfall profits in the power sector" *Climate Policy* **6**(1):49–72

Sijm J, Hers S, and Lise W, 2008a, "The implications of free allocation versus auctioning of EU ETS allowances for the power sector in the Netherlands" ECN-E-08-056, Petten, The Netherlands

Sijm J, Hers S, Lise W, and Wetzelaer B, 2008b, "The impact of the EU ETS on electricity prices, Final report to DG Environment" ECN-E–08-007, Petten, Petten, The Netherlands

Sijm JS, Chen Y, and Hobbs BF, 2009, "The impact of power market structure on the pass-through of CO2 emissions trading costs to electricity prices—a theoretical approach" Paper presented at the EAERE2009 conference, 24–27 June, Amsterdam

Sijm J, Neuhoff K and Chen Y, 2006, "CO_2 cost pass-through and windfall profits in the power sector" *Climate Policy* **6**(1): 49-72.

Solier B & Jouvet PA, 2011, "An overview of CO2 cost pass-through to electricity prices in Europe" Technical Report 2011-08, Chaire Economie du Climat. Available from: http://www.chaireeconomieduclimat.org/wp- content/uploads/2011/10/ 11- 07- 12- Cahier- R- 2011- 8- Solier- and- Jouvet- Pass- through- 2.pdf.

Spencer T and Guerin E, 2012, "Time to reform the EU Emission Trading Scheme" *European Energy Review*, 23 January 2012

Stahn, K. 2006, "Has the Export Pricing Behaviour of German Enterprises Changed? Empirical Evidence from German Sectoral Export Prices" *Economic Studies* 37/2006, Deutsche Bundesbank, Frankfurt am Main.

Sterk W and Mersmann, F, 2011, "Domestic Emission Trading Systems in Developing Countries – State of Play and Future Prospects" JIKO Policy Paper 2/2011

Grubb M, Tindale S, Henningsen J, and Neuhoff K, 2012, "Strengthening the EU ETS: Pros and cons of available options" *Climate Strategies Report, March* 2012

Walker, N, 2006, "Concrete Evidence? An Empirical Approach to Quantify the Impact of EU Emissions Trading on Cement Industry Competitiveness" Planning and Environmental Policy Working Paper PEP 06/10, Department of Planning and Environmental Policy, University College Dublin, Dublin.

Weber, T, 2010, "Carbon Markets and Technological Innovation" *Journal of Environmental Economics and Management,* ***60*** *(2) p115-132*

WCI, 2010, "Design for the WCI Regional Program" July 2010

World Bank, 2010, "Tokyo's Emissions Trading System: A Case Study" *Directions in Urban Development* June 2010

Wrake, M, Burtraw, D, Löfgren, A, & Zetterberg, L, 2012, "What have we learnt from the European Union's emissions trading system?" *AMBIO: A Journal of the Human Environment* pp. 1–11 Available from: http://www.springerlink.com/index/YU05415551083434.pdf.

Wyns T, 2012, "The EU allowance surplus problem in Europe's Emissions trading system" *CCAP Europe*

Zachmann G and C von Hirschhausen, 2008, "First Evidence of Asymmetric Cost Pass- Through of EU Emissions Allowances: Examining Wholesale Electricity Prices in Germany" *Economics Letters* **99**(3), 465–469.

Zhao J, Hobbs BF, and Pang JS, 2010, "Long-run equilibrium modeling of alternative emissions allowance allocation systems in electric power markets" *Operations Res*, **58**-3, 529-54